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RESULTS OF THE SECOND FLIGHT TEST OF THE
LORAN-C RECEIVER/DATA COLLECTION SYSTEM

Reported are the results of a second flight test of the LORAN-C system under development at Ohio University using a variation of the techniques used for the first flight test.

by

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I. INTRODUCTION

Research at Ohio University is continuing with the aim of developing a low-cost LORAN-C navigation system. The components of this system which have been developed thus far are a phase-locked-loop receiver [1] and a microcomputer development system. [2] The microcomputer is being used as a means of testing and implementing software to handle sensor control and navigation calculations. Currently, the microcomputer is being used to collect and record data from the receiver [3] in addition to development work.

With these components, it has been possible to record receiver data over a period of time and then reduce this data to obtain statistical information. It is particularly interesting to load the equipment developed in the laboratory into an aircraft and collect data while in flight. For initial flight tests, some important considerations are how well the entire system will perform in the field, signal strength levels while on the ground and in the air, the amount of noise present, changing of signal-to-noise ratio for various aircraft configurations and maneuvers, receiver overloading due to other equipment and antennas, and the overall usefulness of LORAN-C as a navigation aid.

It was realized at the outset that the first tests would be performed without a data reference, such as a tracking radar. The data could be plotted on a map which would show effects such as noise in the receiver and propagation changes at sunrise or sunset. Some idea of system accuracy can be obtained by comparing the plotted path with recorded events such as crossing a VOR, flying over a good landmark, taxiing, takeoff and landing, etc.

II. FIRST FLIGHT TEST AND THE NEXT STEP

The first flight test [4] was performed by flying along a constant LOP (line-of-position). Prior to the flight, the path was calculated and plotted on a sectional aeronautical chart and topographic maps. Landmarks along the route were then numbered and listed on a log sheet. Part of the setup included a meter indicator which showed deviation from the LOP; the meter was calibrated in microseconds which would show the amount of correction needed. The flight proceeded by reference to the LOP indicator and as a landmark was passed, an event mark was stored in the microcomputer.

Some problems were noted during this flight test. There was some uncertainty at first about the sense of the needle. Also, the indicator registered at a rate which was too fast for the pilot to follow, especially for minor deviations in the output from the receiver. There were also problems encountered in locating landmarks when the aircraft strayed from course.

Useful data was obtained from this flight, and it showed that the receiver performed remarkably well in the aircraft. However, it was decided that it would be better to choose a flight path and fly this path as closely as possible while collecting data. The results would then be compared to the pre-determined flight path to look for any differences. Once again, good landmarks could be entered into the computer memory.

By flying a closed polygonal path, any bias in the system could be noted by the deviations in one or more of the legs.

III. DEVELOPMENT OF THE SECOND FLIGHT TEST

The main problem presented for the second flight test was the selection of a suitable flight path. Good paths may include highways, railroad tracks, or other topological features which are fairly straight. Due to the geographical terrain in the test area, it was felt that the best course to follow would be to fly VOR radials and make at least two visual crossings over the VOR's. Figure 1 is a map of the VOR stations and airports in the Athens, Ohio area. From this, it may be seen that there are several possibilities as to a test course. The distance between VOR stations should be kept to a minimum so that radial spread will not dilute the accuracy of the data to a serious degree. Based on the possible life of the battery used to power the computer, it was thought best to limit the trip to 95 - 130 km. or a total flight time (including time on the ground) of two to three hours.

The path chosen is shown in Figure 2. After departing from the runway, the 075 inbound radial to Parkersburg would be intercepted. After crossing the VOR, a loop would be made to cross the VOR a second time coming out of the 324 outbound radial. Approximately one-half the way to Zanesville, a switch would be made to the 144 inbound radial to Zanesville. Again, a loop would be made, crossing over the VOR and flying on the 205 outbound radial to Athens. The trip would end by flying directly over the end of the 024 runway.

IV. THE SECOND FLIGHT TEST

A very similar procedure that was used in the first flight test was used for the second. A larger battery with a higher capacity was used to power the KIM-1 micro-computer system; the receiver was powered from its own dry-cell battery pack. Again, the ADF sense antenna was connected to the receiver through a preamplifier/filter mounted at the aircraft console. The signal was routed through coaxial cable from the antenna to the preamplifier to the receiver. Since the flight course was not coincident with an LOP, the LOP indicator was not used. The U.S. East Coast (9930) LORAN-C chain was selected for this flight using the Cape Fear - Nantucket (pair Y) and Cape Fear - Dana (pair Z) stations. Figure 3 shows a plot of the collected data.

After taking off from the Ohio University Airport, a turn was made toward the VOR radial to Parkersburg. The actual course (Figure 4) was south of the radial for approximately 20 kilometers. The rest of the trip to Parkersburg was made on the desired radial as verified by landmarks taken along the way.

After crossing the VOR, a loop was made to get on the next radial for Zanesville. The loop was made north of the desired radial, and as a result, it wasn't picked up until over the VOR a second time. The switch to the Zanesville VOR was made at approxi-

mately the halfway point. The glitch in Figure 3 indicated this, although it is likely that the receiver or computer lost lock momentarily at that point. The data along the radial and the data for the VOR crossing are 1.5 km. to the south of the actual path. This is due in part to a fixed bias in the TD-to-position routine and the weak signal from Nantucket.

The first crossing over Zanesville is again 1.5 km. south. A loop was made to get on the radial back to Athens, but the radial was missed. Instead, a fixed circle of radius 15 km. was flown around the VOR. When it was noticed that the radial had been missed, the plane was flown back to catch the proper radial on the back side of the VOR in order to get a second pass over it. The data indicates rather well the semi-circle flown around the VOR and the sharp turn made to get back on the radial.

The last leg was flown back to the airport and as can be seen, the collected data corresponds well with the actual flight course which was augmented with many landmark sightings.

This trip was made in the mid-afternoon. It was noticed at Zanesville that the TD reading for the Nantucket pair was beginning to fluctuate. This could be explained by the fact that the sun was beginning to set at Nantucket. It has been observed in the lab that there are changes in the TD readings for weak signals at sunset or sunrise. Another factor which had an effect on the collected data was the overloading of the receiver when the communications radio was used. The ADF antenna is located very close to the communications antenna which would cause the overloading problem. Although the receiver would not lose lock if the transmission was not longer than 10 seconds, the antenna used for the LORAN-C receiver should be kept away from any transmitting antennas.

V. CONCLUSIONS

Despite the lack of a data reference, it has been shown that the LORAN-C data collected from this flight test is fairly reliable. There is still some problem with using a weak station because of skywave contamination. This should be solved by the establishment of new chains with strong stations located closer to this area. For future flight tests, it is hoped that one of these chains may be used, particularly the U.S. Northeast (9960) chain which has given good signals in the lab. The first two flight tests have shown that the LORAN-C equipment can track such maneuvers as tight turns fairly well. For future flight tests, the data collection rate will be stepped up to allow more precision. It is also hoped that the next flight tests can be made to determine the fix repeatability for LORAN-C receiver.

VI. ACKNOWLEDGEMENTS

Special thanks go to Mr. Delmar G. Pullins who was the pilot for this flight test and was instrumental in locating landmarks along the flight course. Others who participated in this flight test were Mr. Ralph W. Burhans, project engineer; Dr. Robert W. Lilley, assistant director; Mr. James D. Nickum, student intern and Mr. Edwin D. Jones, student intern.

VII. REFERENCES

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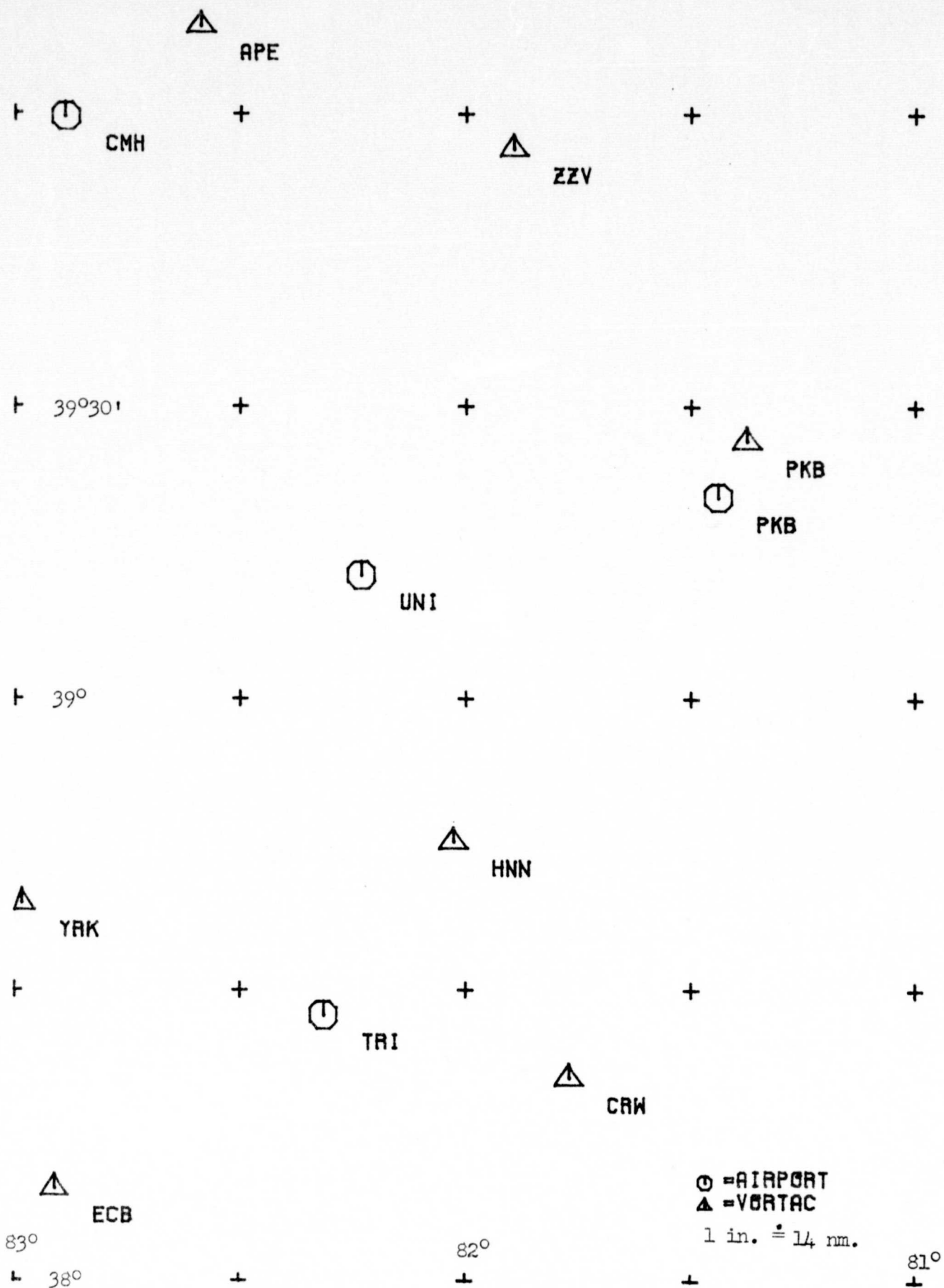


Figure 1. Airports and VOR's in Southeast Ohio Area.

82°20'
┆ 40°

82°
+

81°30'
+

┆ 39°30'

+

+

UNI

ZZV

PKB

⊙ = AIRPORT
Δ = VORTAC
1 in. = 6.9 nm.

82°20'
┆ 39°

+

+

Figure 2. Course for Second Flight Test.

82°20'
+ 40°

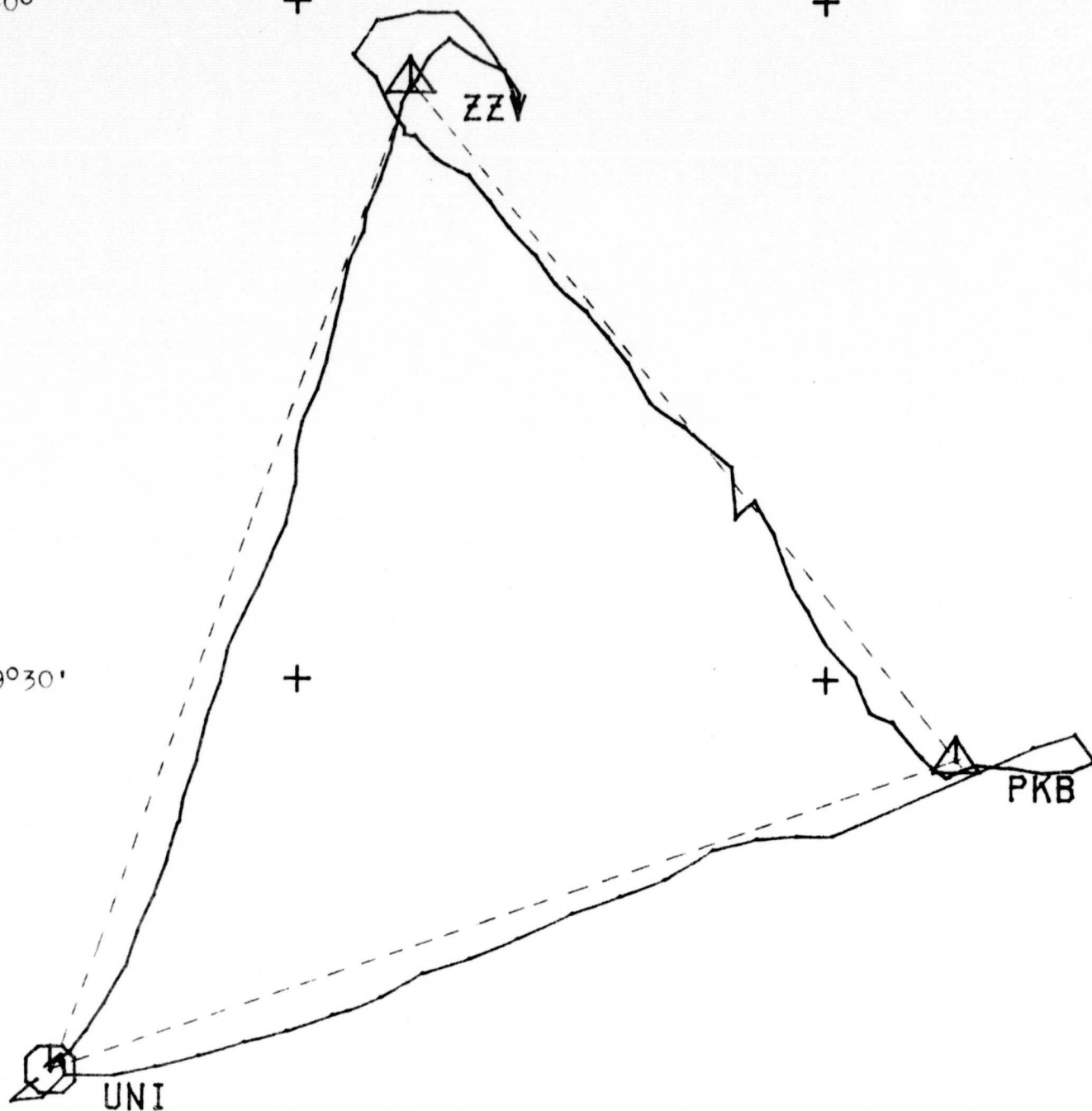
82°
+

81°30'
+

+ 39°30'

+

+



⊙ = AIRPORT

△ = VORTAC

1 in. = 6.9nm.

82°20'
+ 39°

+

+

Figure 3. Flight Data Collected.

82°20'

├ 40°

82°

+

81°30'

+

├ 39°30'

+

+



UNI



ZZV



PKB

⊙ = AIRPORT

△ = VORTAC

1 in. = 6.9 nm.

82°20'

├ 39°

+

+

Figure 4. Course Flown (Approximate - from landmarks).